gravelly hollow, which was no doubt the dried up bed of the river. This was the general character of the rivers, and it was quite possible that for several years you might take a steamer up the Darling 1500 or 1800 miles, nearly to its source, and that for the next ten years you would not be able to take a single boat up. This resulted from the want of elevation in the mountain ranges. The Murray River, which was always navigable and a perpetually flowing stream, took its rise from the Australian Alps, the summits of which were covered for the greater part of the year with snow, the melting of which kept up a constant supply of water. Still, even with this river it was only occasionally that you got an opening into it from the sea. The mouth was blocked up with sand, and there was not a greater depth than three feet over it, the drainage of that part of the country not being sufficient to keep the mouth of the river open, as it would do in a country where there was a regular fall of water. He did not believe with Colonel Gawler that Lake Torrens was only the ancient embouchure of the streams he had mentioned, but the present one, and the only one it ever had, and that no more water had ever come out on an average of years than came out now. These facts proved to him that there could not be a well-watered country over the whole of the interior of Australia. There might be large oases; but generally it must be a dry country, or else the overplus of drainage would come out in considerable rivers somewhere. The fact mentioned by Gregory that after ascending the basin of the Victoria and crossing the water-parting at no greater height than 1400 feet, he soon came down upon salt lakes, proved that it was an arid country, in which the evaporation was greater than the waterfall, or the lakes would not have been salt.

The springs mentioned by Sir Richard Macdonnell were very curious and interesting, and he was for some time puzzled by them. It appeared to him that the water must contain a great quantity of carbonate of lime in solution, and that these cups were nothing more than calcareous tufa that had been deposited gradually by the overflow of the spring, until finally the deposit made a mound, through which the water continued to well out, just as in the case of the siliceous mounds round the geysers in Iceland.

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The third Paper read was—

3. *On Typical Mountain Ranges.* By William Spottiswoode, Esq., F.R.G.S.

In an elaborate memoir published in the 'Petersburg Transactions,' Series VI. tom. viii., Dr. Abich has grouped the mountain ranges of Western and Central Asia under four heads, and deduced a mean direction for each group; but in doing so he has simply taken the arithmetical mean of the direction of the ranges under consideration, without reference to their length or their elevation. Mr. Spottiswoode shows the method by which the calculation of a mean direction ought justly to be made; not only by taking these omitted data into account, but also by using the calculus of probabilities to find whether or no, that mean direction be a *typical* one. Mr. Spottiswoode's object is not so much to correct Dr. Abich's conclusions on this particular point, which are, in fact, independent of the largest

correction afforded by the calculations in the present instance, as to suggest and exemplify a new problem in physical geography.

He accordingly examines one of the groups of Dr. Abich, consisting of 24 mountains. He first finds the mass of each from the data of their length, of their elevation, and of the slope of their sides, which latter, in absence of better information, he assumes to be the same in every case. Now this mass corresponds, in mathematical language, to the '*weight*' of an observation, and is represented by $w$.

Next, he takes $\theta_1, \theta_2 \ldots . \theta_n$ as the angles between the several mountain ranges and the parallels of latitude, drawn through the middle points of the ranges; in which case, by well-known formulæ, the probable typical direction of the chain will be

$$\Theta = \frac{\Sigma w\theta}{\Sigma w}$$

Moreover, the probable *errors* (or deviations) of the various ranges from the typical range will be $e_1 = \Theta - \theta_1 \ldots . e_n = \Theta - \theta_n$.

The mean error (deviation) of an observation (range), whose weight (mass) is unity, will be

$$\eta = \sqrt{\frac{\Sigma w e^2}{n-1}}$$

The mean errors of $\theta_1, \theta_2 \ldots . \theta_n$ respectively, or the "errors (deviations) to be feared" will be

$$\varepsilon_1 = \frac{\eta}{\sqrt{w_1}}, \ \varepsilon_2 = \frac{\eta}{\sqrt{w_2}}, \ \ldots \ \varepsilon_n = \frac{\eta}{\sqrt{w_n}}$$

And the mean error E (deviation) of $\Theta$, or "error (deviation) to be feared" will be

$$E = \frac{\eta}{\sqrt{\Sigma w}}$$

So that $\Theta$ will lie between the limits $\Theta \pm E$.

An ample numerical investigation is made of all these quantities; they are tabulated, and they are compared with a theoretical scale of precision in the way well known to all who are familiar with the subject of probabilities. The result is, that not only has the mean direction of these mountain masses been accurately ascertained, but it is also made clear that the direction in question is more than a mean direction—that it is a typical one. In other words, we have a direct numerical value (and it is in this case a large one) for the probability that the directions of the different mountains forming this group are due to a single cause, and not to many independent causes; and, consequently, the geologist and the physical philosopher will have good grounds to go upon in seeking some common agency which has caused their upheaval.

"In this way the calculus of probabilities, though one of the most abstract and refined branches of mathematics, and in itself incapable of interpreting any natural phenomena, may still serve as a check and a guide to the physical philosopher, by pointing out where he may and where he may not employ his study of causes, with reasonable hope of a successful result."

The CHAIRMAN, in returning the thanks of the Society to Mr. Spottiswoode for his communication, said this subject of the direction of mountain chains had for a considerable period given rise to discussions among geologists, and had formed a subject to which M. Elie de Beaumont in France had given his most mature consideration.

GENERAL J. E. PORTLOCK, R.E., F.R.G.S., said he would only offer a few words on a subject so complicated to point out the value of such researches. Everybody is now aware that the earth is not in the condition in which it proceeded from the hands of the Creator. The mountains were not originally in the position or under the circumstances in which we now saw them, but they have been lifted up to their present position. It naturally occurs to us to inquire how this work had been performed? Was there a regular progression in it, was it done all at once, or was it done in successive epochs? This is a point which has engaged the attention of geologists for many years past. M. Elie de Beaumont has particularly made it the object of his inquiries, and has established that there were at least twelve successive epochs of disturbances, or of elevation, each of which produced some evidence of the direction of its action on the surface of the earth. Now, an inquiry, such as Mr. Spottiswoode has entered upon, will, by the aid of high mathematical analysis, lead us to this kind of conclusion. We are looking at a range of mountains; we examine not merely their present direction, but their magnitude and weight. We consider, therefore, each range in its length, its height, and consequently its magnitude and weight, and by the calculus of probability we arrive at the conclusion that such particular line exhibits the direction in which the greatest amount of force had been applied; and that is assumed as the *typical* direction, or the direction in which nature had applied an elevatory force in the greatest and most general way. Of course, there will be diverging lines: on one side diverging in the one direction, and on the other diverging in the opposite; but these balance each other, and we arrive at a typical direction, which is not merely the mean as referred to direction alone, as was the case in the investigations referred to by Mr. Spottiswoode, but a result in which the weight of each part is taken into consideration as a necessary element in determining the direction and magnitude of the force which had been applied to the elevation of the chain. This, of course, is a most valuable elementary result as a guide to the physical inquirer in his researches, when endeavouring to bring positive facts under the domain of some definite law, and on this ground General Portlock looks upon every application of mathematical science to natural questions to be of the very utmost importance.

The CHAIRMAN, before adjourning the meeting, called attention to a series of beautiful illustrations of Texas and Mexico, which had been exhibited to the Society by the Abbé Domenech, who was about to publish in this country a work on that region, which would soon appear. The Abbé Domenech had spent six years in those countries, and he (the Chairman) was persuaded, from what he had heard from his contemporaries in France, and particularly from missionaries, that no person could be more thoroughly relied upon or more completely enabled to delineate the features of the tract he had explored.